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Comparison of aerial video and Landsat 7 data over ponded sea ice

Thorsten Markus[a,*], Donald J. Cavalieri[b], Mark A. Tschudi[c], Alvaro Ivanoff[d]

[a] Laboratory for Hydrospheric Processes, NASA Goddard Space Flight Center, Code 975, Greenbelt, MD 20771, USA
[b] Laboratory for Hydrospheric Processes, NASA Goddard Space Flight Center, Code 971, Greenbelt, MD, USA
[c] National Center for Atmospheric Research, Atmospheric Technology Division, Boulder, CO, USA
[d] Science System and Applications Incorporated, Lanham, MD, USA

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Abstract

The development of melt ponds on Arctic sea ice during spring and summer is of great importance to the Arctic climate system as it accelerates the decay of the sea ice and greatly reduces the albedo. Both melt pond development and its spatial distribution are needed to understand the surface energy balance in summer. Previously, a technique was developed for classifying summer sea ice characteristics, including the amount of open water, white (snow-covered) ice, wet ice, and melt ponds using Landsat 7 Enhanced Thematic Mapper Plus (ETM+) spectral information. In this paper, we refine this technique through the use of airborne video data coincident with Landsat ETM+ imagery obtained over Baffin Bay on June 27, 2000. The video images, having a resolution of about 1.5 m at an aircraft altitude of 1.4 km, are classified into open water, ponded or wet ice, and unponded sea ice. Comparison of the video and Landsat imagery shows that many of the melt ponds are too small to cover an entire Landsat pixel (resolution of 30 m) so that the Landsat classification scheme would underestimate melt pond fraction. Thirteen high-resolution video images are classified to develop a method to calculate fractions of open water, ponded or wet ice, and unponded ice from Landsat 7 data. A comparison between these classified video images and Landsat retrievals yields a correlation coefficient of 0.95 with rms errors of less than 9% for the two ice types and 2% for open water. Comparisons of Landsat and video analyses not used in the development of the algorithm yield correlation coefficients of 0.87 for open water, 0.68 for ponded ice, and 0.78 for unponded ice. The rms differences are 10%, 8%, and 11%, respectively.

Keywords: Aerial video; Landsat 7; Ponded sea ice

1. Introduction

During spring and summer, melt ponds on Arctic sea ice are a common feature that cover up to 50% of the sea ice area (Derksen, Piwowar, & LeDrew, 1997; Fetterer & Untersteiner, 1998). Ponds play a critical role in the ice-albedo feedback (Curry, Schramm, & Ebert, 1995) as the albedo of wet ice and melt ponds is considerably lower (as low as 0.2 for 30-cm-deep ponds; Grenfell & Maykut, 1977) than the albedo of dry snow (typically greater than 0.8 (Perovich, Grenfell, Light, & Hobbs, 2002). Thus, there is a need for accurate representations of melt pond albedo, fraction, and morphology in climate models to properly portray the response of the Arctic surface to solar forcing (Barry, 1996; Morassutti, 1991; Podgorny & Grenfell, 1996; Robinson, Serreze, Barry, Scharfen, & Kukla, 1992).

In addition to the influence of ponds on the Arctic surface energy budget, the presence of ponds causes ice concentration estimates from passive microwave observations to be underestimated during summer (Cavalieri, Gloersen, & Campbell, 1984; Fetterer & Untersteiner, 1998). An accurate estimate of ponded ice cover would allow for the quantification of these errors and thus aid in the development of improved passive microwave algorithms.

In previous studies, Perovich, Maykut, and Grenfell (1986) and Morassutti and LeDrew (1996) measured the spectral albedos of sea ice at different stages of ponding and noticed the significantly stronger decline in albedo with increasing wavelength of melt ponds compared to unponded ice. Tschudi, Curry, and Maslanik (1997, 2001) used these spectral reflectance differences to determine melt pond coverage on sea ice from video imagery of the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment study area. Their classification scheme distinguishes among ponded ice, unponded ice, and open water. Markus, Cavalieri, and Ivanoff (2002) used a spectral classification procedure to label Landsat pixels as either open water, melt ponds, wet or bare ice, and snow-covered or bare white ice. Similar to the approach by Tschudi et al., the distinct bluish appearance was utilized to extract melt pond pixels. The Landsat spectral albedos were in good agreement with in situ measurements by Perovich et al.

* Corresponding author. Tel.: +1-301-614-5882; fax: +1-301-614-5558.
E-mail address: Thorsten.Markus@nasa.gov (T. Markus).

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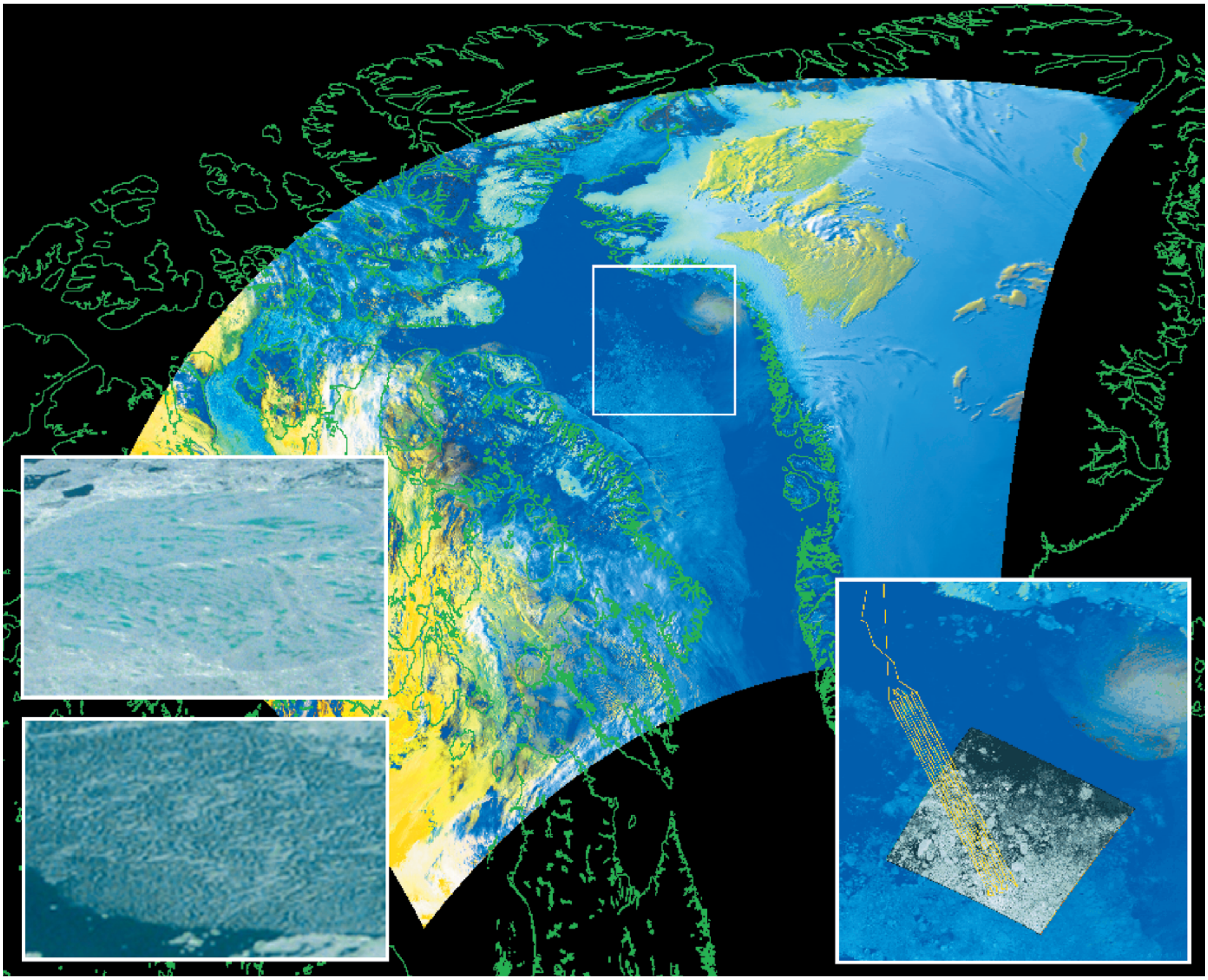

Fig. 1. AVHRR scene of the Baffin Bay region on June 27, 2000. The inset in the lower right corner shows a gray-scale Landsat 7 image for the same day; aircraft tracks are in yellow. The digital photos in the lower left corner show two different kinds of melt ponds observed.

In this paper, we made use of high-resolution aircraft video imagery to refine the detection of melt ponds using Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data. After a brief description of the data (Section 2) and the limitations of current methods (Section 3), we describe the methods developed (Section 4) and investigate errors and sensitivities (Section 5) before applying the Landsat method to larger scales (Section 6).

7. Conclusions

We have presented a new algorithm with which to retrieve the spatial distribution of ponded ice, unponded ice, and open water from Landsat 7 ETM+ imagery. Overall, the results agreed quite well with the aircraft video data of a portion of Baffin Bay obtained on June 27, 2000. A sensitivity study has shown that occasional large differences may be explained by uncertainties in the choice of thresholds in the video data as well as the tiepoints in the Landsat algorithm.

Unfortunately, the areas overflown did not show any blue melt ponds in either the video or the Landsat imagery so that spectral signatures as observed by Tschudi et al. (1997, 2001) and Markus et al. (2002) could not be directly utilized, although the Landsat algorithm described in this paper makes use of a blue spectral signature to aid in melt pond detection, should such a signature occur. A reason for the lack of observed "blue" melt ponds may be the advanced stage of melt at the end of June, together with the relatively thin first-year ice cover in Baffin Bay, so that most melt ponds have either melted through or are atop thin ice. Other areas may have been affected spectrally by sea water that flooded the top of ice floes.

The retrieval of the distribution of ponded and unponded ice may be extended to other areas of the Arctic that are covered by Landsat. The primary challenge for this technique to work in other areas is identifying proper spectral reflectance tiepoints, as pond spectral signature can vary greatly. Therefore, as was done in this study, the accuracy of classification is improved with higher resolution spectral reflectance mapping of ponded and unponded ice within the Landsat scene. It would be of great value if Landsat algorithms were able to distinguish between melt ponds and sea water on top of the ice. This capability needs to be explored using high-quality aerial digital imagery with Landsat 7 ETM+.